High-Q parallel plate resonator for V-band in MCM-D technology

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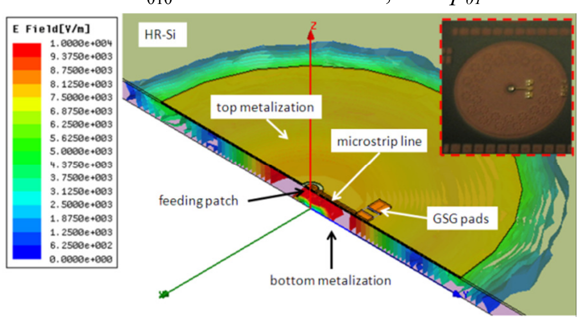
Abstract- This paper presents a high-Q parallel plate resonator for V-band in MCM-D technology. The resonator is defined by two cylindrical parallel plates sandwiching a stack composed of benzo-cyclobutene (BCB) and high resistivity silicon (HR-Si). The TM_{010} mode of resonance is excited by a patch feed. This is a low technological complexity implementation offering a high-Q resonator alternative, at V-band for e.g. oscillator's reference.

Planar passive components offer limited performance at mm-wave in terms of unloaded quality factor (Qo), which is limited to 30 below 10 GHz and is decreasing with an increasing operating frequency [1]. However, very good performance characterizes cavity resonators, the latest require advanced micromachining technologies for manufacturing at V-band, e.g. micromachined metalized cavities or substrate integrated vias. Alternatively, as proposed in this paper, parallel plate resonators represent instead a low technological complexity implementation. The parallel plate resonators are realized in IMEC's MCM-D, a cross section of which is shown in Fig. 1a [2]. The MCM-D is composed of three metallizations realized by successive sputtering on benzo-cyclobutene (BCB), (ε_{BCB} = 2.65, tan δ = 0.008). The first layer, 1 µm Al is sputtered directly on top of the high resistivity silicon (HR-Si), (ε_{HR-Si} = 11.9, tan δ = 0.0026) and is covered by 4.4 µm BCB. The second layer, 5 µm Cu is covered by 8.5 µm BCB. The third layer is an electroplated stack of 10 µm Cu/Ni/Au. The stack of BCB and HR-Si results in a composite relative permittivity (ε_r) which is evaluated using (1). Assuming a magnetic wall at the edges of the resonator, the resonance frequency is given by (2), following [3].

$$\varepsilon_r = \frac{\varepsilon_{BCB}\varepsilon_{HR-Si}(d_{BCB}+d_{HR-Si})}{\varepsilon_{BCB}d_{HR-Si}+\varepsilon_{HR-Si}d_{BCB}} \quad (1) \qquad\qquad f_0 = \frac{cp_{01}}{D\pi\sqrt{\varepsilon_r}} \quad (2)$$

with c the free space light velocity, D the diameter of the disk and ε_r the relative dielectric constant obtained using (1). Here the TM_{010} mode is considered, with p_{01} = 2.405 the first root of the zeroth order Bessel's function.



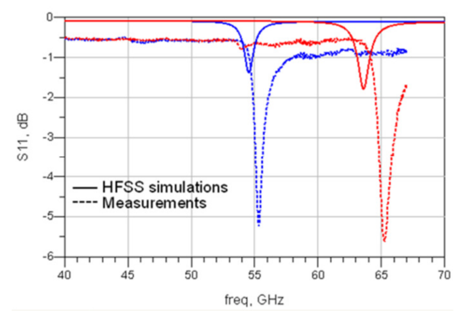


Figure 1: a) High-Q parallel plate resonator, field distribution in MCM-D's cross section and in enclosure, picture of the implemented resonator. b) Measurements and HFSS simulations at both 55 and 65 GHz.

The parallel plate resonator is excited by a central patch in MCM-D's second metallization, as can be seen in Fig. 1a. The diameter of the patch (p = 90 µm) controls the coupling coefficient (κ). The slot opening around the patch is s = 50 µm. The patch feed, is connected by a short vias through the 8.5 µm BCB to a microstrip line in the third metallization of 20 µm width and 300 µm long. The microstrip line is connected to a GSG configuration, composed of three 80 µm x 80 µm pads, placed with a pitch of 120 µm. The measurements, shown in Fig. 1b are higher in frequency and present a higher coupling coefficient than the simulations, which is believed resulting from a slightly larger p and s. The diameter implemented at 55 & 65 GHz respectively (D_{imp} = 1990 & 1680 µm) are larger than the analytical designs (D_{anal} = 1200 & 1020 µm) because the detuning due to the patch feed is not accounted by (1) and (2). The quality factors are extracted from measurements (microstrip line included) with QZERO [4], at 55.21 GHz and 65.03 GHz, respectively as follows: Q_0 = 95.4 ± 4.2, κ = 0.468 ± 0.058 and Q_0 = 80.1 ± 5.0, κ = 0.65 ± 0.09. These results represent a very good performance at V-band.

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